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Prepared by:

R. W. Nicholls, D.Sc., Ph.D., F. Inst. P.
Senior Professor of Physics,
University of Western Ontario,
London, Ontario, Canada.

(Visiting Professor of Aero-and Astrophysics
Stanford University, June - December 1964)

CONTENTS

1: INTRODUCTION 1

2: OVERALL RESEARCH PROGRAMME 1

3: PERSONNEL 2

4: SPECIFIC RESEARCH ACTIVITIES 4

4.1 Experimental 4

4.2 Theoretical 6

5: PUBLICATIONS 8

5.1 Published Papers 8

5.2 Papers Submitted to Journals 9

5.3 Graduate Student Theses 9

1: INTRODUCTION

This report summarises research activities in Laboratory Astrophysics and Aeronomy of The Molecular Excitation Group, University of Western Ontario during the six-month period August 1st 1964 - January 31st, 1965. Progress has been very pleasing. A number of the graduate students have reached the successful completion of their research and are writing theses or have been awarded higher degrees. Dr. Nicholls spent the period June-December 1964 as Visiting Professor of Aero- and Astrophysics, Stanford University. Nevertheless during that time he maintained close contact with the group by telephone and mail. Drs. Ferguson and Fraser retained day to day supervision of the activities in London, Ontario until Dr. Nicholls return to this University in mid-January 1965.

During the report period nine papers have appeared in the journals and seven more have been submitted for publication on the work of the group. Four theses (2 Ph. D. and 2 M. Sc.) have been completed and successfully defended by graduate students working on the programme.

2: OVERALL RESEARCH PROGRAMME

The overall research programme has changed very little from the last report and includes activities in:

Experimental

Intensity measurements on molecular spectra

General molecular spectroscopy of electronic band systems

Atlas of molecular spectra

Shock tube spectroscopy

Plasma jet studies

Electron beam spectroscopy

Ion beam spectroscopy

X-radiolysis of gases

Ablation studies

(Continued)

Impact flash spectroscopy

Laser excitation of powdered solids

Theoretical

Studies of molecular potentials and wave functions

Studies of derived quantities of vibrational wave functions

Atomic (e+H) collisions

3: PERSONNEL

The personnel of the research group has changed somewhat during this report period.

Drs. D. C. Tyte and G. R. Hebert joined the group on a permanent basis as faculty members during the summer. Dr. G. V. Marr (Reading University) was with the group for the summer. A number of students completed their studies for higher degrees during the report period as follows. Mr. N. A. Doughty received his Ph. D. and left to take up his Rutherford Memorial Post Doctoral Fellowship at University College London, England. Mr. R. A. Koehler was awarded his M. Sc. and resumed his appointment as graduate technical assistant (Electronics), Mrs. Murty gained her M. Sc. and resumed her appointment as Graduate Technical Assistant. Messers G. Drake (from McGill) and J. Myer (from UWO) joined the group as graduate students. Mrs. S. Innanen joined the group as a Graduate Technical Assistant.

Faculty

Dr. R. W. Nicholls, Senior Professor of Physics (Director)

Dr. H. I. S. Ferguson, Associate Professor of Physics (Assoc. Director, Experimental)

Dr. P. A. Fraser, Professor of Physics (Assoc. Director, Theoretical)

Dr. G. R. Hebert, Assistant Professor of Physics (Spectroscopy)

Dr. G. S. Rose, Assistant Professor of Physics (Plasma Studies)

(Continued)

Dr. D. C. Tyte, Assistant Professor of Physics

Dr. R. C. Murty, Assistant Professor of Physics (Molecular Spectroscopy)

Mr. W. R. Jarmain, Lecturer in Physics (Theoretical Studies)

Visiting Professors

Dr. G. V. Marr, Lecturer in Physics, University of Reading, England (Summer 1964)

Graduate Students (Supported by scholarship where indicated)

Mr. V. Degen

Mr. G. Drake (NRC Scholarship)

Mr. N. A. Doughty (Commonwealth Scholarship) (Now at University College London)

Mr. J. P. Fallona (Ontario Scholarship)

Mr. M. Kraidy (NRC Studentship)

Miss I. S. Lee (Ontario Scholarship)

Mr. R. P. Lowe (DRB on leave)

Mr. J. Mentall

Mr. D. McEwen (DRB on leave)

Mr. A. McGregor (NRC Scholarship)

Mr. F. Morgan (NRC Scholarship)

Mr. J. Myer (ORF Scholarship)

Graduate Technical Assistants

Mr. W. Doan (Summer 1964)

Mrs. S. Innanen

Mr. R. A. Koehler

Mrs. M. Murty

Technician

Mr. J. Radema

Secretary

Mrs. D. Sass

4: SPECIFIC RESEARCH ACTIVITIES

4.1 Experimental

4.1.1 Intensity Measurements on Molecular Spectra

Mr. McEwen completed his studies of a number of band systems of N_2, N_2^+ and CO in the vacuum ultraviolet. He has completed his Ph.D. thesis on the work on the intensity distribution in the Lyman-Birge-Hopfield system of N_2, in particular and has shown that its electronic transition moment is independent of internuclear separation. This work has great application to auroral rocket spectroscopy. Dr. Hebert is now working on the CO Fourth Positive system.

Mr. Degen is working on the O_2 Herzberg system, Mr. Fallona is working on a number of NO systems and Mr. Drake is working on a number of shock-excited BeO systems. Dr. Tyte and Dr. Hebert continue their study of intensity measurements on shock excited band systems of oxides and have published a paper on some of this work (see 5.1).

4.1.2 General Molecular Spectroscopy of Molecular Band Systems

Mrs. Murty was awarded her M.Sc. for her work in the geometry of Condon loci of molecular spectra. This work is currently being written up for publication.

4.1.3 Identification Atlas of Molecular Spectra

The second identification atlas (on the N_2 Second Positive System) has been prepared by Drs. Tyte and Nicholls, printed by the University of Toronto Press, and circulated (see section 5.1 below). To avoid administrative difficulties no NASA funds were used in the actual printing of this report. NASA funds were used however in partial support of a number of summer visitors and others who worked on the preparation of this and a number of other atlases.

4.1.4 Shock Tube Spectroscopy

Dr. Tyte continued his study of the physical processes involved in

shock excitation of AlO particles and has been working recently on the precise identification of a new system in the Violet using time resolved absorption techniques. Isotopic studies are anticipated.

Mr. Drake has made a careful study of intensities of BeO bands shock excited, in particular vibration-rotation interaction was studied.

Mr. McGregor continues his shock-tube studies of oscillator strengths of MgH bands.

Mr. Myer has been successfully working on study of ablation of powder particles in a shock tube (see 4. 1. 10 below).

4. 1. 5 Plasma Studies

Mr. Morgan has completed his combined spectroscopic and electrical studies on a plasma jet, and the Ph. D. thesis describing it. He is currently awaiting his Ph. D. oral examinations.

4. 1. 6 Ion Beam Spectroscopy

Mr. Lowe has completed his studies on the spectroscopy of 2-10 KeV Na^+, Li^+, K^+ ion beams in a variety of target gases and is writing his Ph. D. thesis. One paper on this work has been accepted for publication in The Proceedings of the Physical Society (see 5. 1).

4. 1. 7 X-Radiolysis of Gases

Miss Lee has completed her spectroscopic study of the very feeble light emitted when X-rays pass through gases and is writing her M. Sc. thesis.

4. 1. 8 Impact Flash Spectroscopy

Mr. Koehler completed his studies on the 1 microsecond impact flash, and was awarded an M. Sc. for his work which is in process of writing up for journal publication.

4.1.9 Laser Excitation of Powdered Solids

Mr. Mentall has made great progress during the report period in his quantitative spectroscopic studies of the 'flame' arising from laser excitation of a number of powdered solids, notably carbon.

One paper has been published on his early survey work (see 5.1) and he is presenting an oral paper on his later work at the Washington APS meetings.

4.1.10 Ablation Studies

Mr. Myer has successfully developed particle sizing techniques which allow him to make inferences of ablation experienced by metal particles subject to shock excitation from measurement of particle size before and after shock treatment.

4.2 Theoretical

4.2.1 Molecular Potentials and Vibrational Wavefunctions

Mr. Jarmain and Dr. Nicholls are extending the work on the $B^3\Sigma$ state of O_2 to the $A^3\Sigma$ state and are writing up previous work.

4.2.2 Franck-Condon Factors and r-Centroids

Dr. Nicholls has continued his computations of arrays of Franck-Condon factors for many band systems and transitions and has published a number of papers on this work (see section 5.1).

4.2.3 Atomic Collisions (written by Prof. P.A. Fraser)

Perhaps the progress in the past year can best be described by mentioning five projected manuscripts for which the material is either complete or all but complete. The manuscripts for two of these are in preparation. The others will be prepared over the next month or two. The people involved in this work with the writer are N.A. Doughty (graduate student, Commonwealth Scholarship), M. Kraidy (graduate student, NRC Studentship), C.E. Tull (undergraduate summer employee) and Dr. R.P.

McEachran (Research Associate part-time, former NRC Overseas Post-Doctoral Fellow, and the writer's former graduate student).

(i) Doughty, McEachran and Fraser: the work on bound-free transitions of the H^- ion has been considerably extended over previously reported results, and our immediate planned work in this area has been completed.

(ii) Doughty and Fraser: our immediate planned work on the free-free transitions of the H^--ion has been completed with satisfactory and interesting results.

(iii) McEachran, Fraser, Wallace and Tull: a version of a variation-iteration method for solution of atomic collision problems suggested by Saraph and Seaton has been developed. Results may be obtained with much less computer time, and numerous examples from elastic and inelastic collisions are available.

(iv) Kraidy and Fraser: methods of solution of the equations of atomic collision theory - an iterative method of solution supplementing previous methods and a different variation-iteration method.

(v) McEachran and Fraser: extensive results on positron collisions with H-atoms have been obtained.

Other work during the year includes the provision of some results for Professor L. Spruch and colleagues of New York University for the purpose of testing their powerful and elegant methods of solving collision problems. Further, Kraidy and Fraser have commenced the study of the experimentally interesting problem of positron collisions with helium atoms, and Fraser continues his study of positronium collisions with helium.

5: PUBLICATIONS

5.1 Published Papers

The following papers arising from the research programme appeared in the literature during the report period.

The electronic transition moment of the $A^2\Sigma$-$X^2\Sigma$ system of AlO
Proceedings of the Physical Society 84, 830-832, 1964
D. C. Tyte and G. R. Hebert.

Identification Atlas of Molecular Spectra: The N_2 $C^3\Pi$-$B^3\Pi$ second positive system
October 1964
D. C. Tyte and R. W. Nicholls.

Laser excitation of powdered solids
Nature 204, 1295, 1964
H. I. S. Ferguson, J. E. Mentall and R. W. Nicholls.

Franck-Condon factors to high vibrational quantum numbers IV : NO
Journal of Research of the National Bureau of Standards 68A, 535-540, 1964
R. W. Nicholls.

A theoretical study of the O_2 $X^3\Sigma_g^-$ - $B^3\Sigma_u^-$ photodissociation continuum
Proceedings of the Physical Society 84, 417-425, 1964
W. R. Jarmain and R. W. Nicholls.

Interpolation of Franck-Condon factors
Nature 204, 373, 1964
R. W. Nicholls.

Some further aspects of laboratory astrophysics and space science
Canadian Aeronautics and Space Journal 10, 309-312, 1964
H. I. S. Ferguson and R. W. Nicholls.

On the relationship between r-centroid and band frequency
Proceedings of the Physical Society 85, pp 159-162, 1965
R. W. Nicholls

Franck-Condon factors for the Gaydon-Green system of N_2
Journal of Chemical Physics 42, 804, 1965
R. W. Nicholls.

5.2 Papers Submitted to Journals

The following papers have been submitted to journals or are in press.

A microsecond rise-time multi-output amplifier for shock-tube heat-transfer gauges
Journal of Scientific Instruments
R. A. Koehler.

Franck-Condon factors to high vibrational quantum numbers V: O_2
Journal of Research of The National Bureau of Standards (In press, 1965)
R. W. Nicholls.

Franck-Condon factors to high vibrational quantum numbers VI: C_2
Journal of Research of the National Bureau of Standards (In Press, 1965)
R. W. Nicholls.

The distribution of rotational energy in N_2^+ excited by 3 Kev Li^+ ions
Proceedings of the Physical Society
R. P. Lowe and H. I. S. Ferguson.

Franck-Condon factors for the H_2 Lyman band system
Astrophysical Journal 141 (Feb. 15, 1965)
R. W. Nicholls.

The effect of environmental conditions on band strengths
Journal of Quantitative Spectroscopy and Radiative Transfer (In press)
D. C. Tyte.

The elastic scattering of low energy positrons by atomic hydrogen
Proceedings of the Physical Society (submitted)
R. P. McEachran and P. A. Fraser.

5.3 Graduate Student Theses

M.Sc.

M. F. Murty (1964)
"Condon loci of diatomic molecular spectra"

R. A. Koehler (1965)
"Spectroscopic study of the impact flash"

Ph. D.

N. A. Doughty (1965)
" The negative hydrogen ion absorption coefficients"

D. J. McEwen (1965)
"Intensity measurements on the Lyman-Birge-Hopfield system of N_2"